ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ97-454

INTEGRATION OF ISTEA AND DATABASES

Final Report

Prepared by:
William Roetzheim
Marotz, Inc.
13518 Jamul Drive
Jamul, CA 91935

August 1997

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

Technical Report Documentation Page

1. Report No.
FHWA-AZ-97-454

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

Integration of ISTEA and Databases

5. Report Date
August 1997

6. Performing Organization Code

7. Authors
William Roetzheim

8. Performing Organization Report No.

9. Performing Organization Name and Address

Marotz, Inc.
13518 Jamul Drive
Jamul, CA 91935

10. Work Unit No.

11. Contract or Grant No.

SPR-PL-1-(51) 454

12. Sponsoring Agency Name and Address

ARIZONA DEPARTMENT OF TRANSPORTATION
206 S. 17TH AVENUE
PHOENIX, ARIZONA 85007

Project Manager: John Semmens

13.Type of Report & Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

ADOT's ISTEA and related systems contain a wealth of valuable information. However, lack of integration amongst these systems prevents ADOT from realizing the full value this data may provide if accessible to a wider audience.

As a part of determining an appropriate integration strategy, it is important to consider the findings that resulted from executive surveys and interviews. A summary of key findings includes the following:

Integration is expected to offer new opportunities and efficiencies although substantial cost savings do not appear likely primarily due to resource limitations.

There is a need for better performance metrics. Availability and use of measurement information must be carefully considered.

Integration should be small in scope, focused, and gradually implemented. Integration must be affordable using existing resources. Systems must be accessible in user friendly formats. Technical skill levels of potential users are limited.

Based upon our research and understanding of ADOT resources and needs, it is our recommendation that ADOT pursue development and implementation of the INFACCS system (database link) to achieve the goal of data integration. This system has been demonstrated to the satisfaction of Marotz and ADOT TAC members and has earned the support of both groups.

17. Key Words

transportation planning, transportation databases, ISTEA management systems

18. Distribution Statement
Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

23. Registrant's Seal

19. Security Classification

Unclassified

20. Security Classification

Unclassified

21. No. of Pages

155

22. Price

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

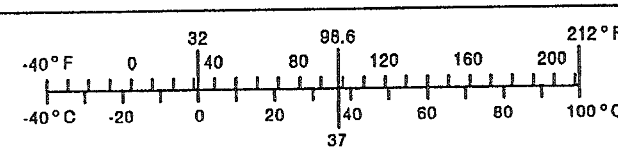


Table of Contents

Overview

In July of 1996, Marotz, Inc. began a study of ISTEA database integration for the Arizona Department of Transportation (ADOT). Business, database, and architectural analyses were performed, and candidate tools were considered to determine the feasibility, goals and recommended direction of the integration.

Initial Kick-Off and Interviews

The project began with an introductory kick-off meeting at ADOT. Technical Advisory Committee (TAC) members and Marotz reviewed and agreed on the project plan. ADOT systems within project scope were identified as well as points of contact for each system.

A series of interviews were arranged with ADOT managers for the purpose of gathering information regarding each department's technical requirements, capabilities and needs. Comprehensive documentation outlining ADOT strategies, architecture, data and operations was provided to assist in defining current infrastructure.

Data Flow Diagrams and Joint Application Development Session

Based upon the initial interviews and applicable documents, specific ISTEA data flows were diagrammed using the System Architect CASE tool. These diagrams were reviewed and further refined during a joint application development session (JAD) at ADOT that involved representatives from ISTEA and related departments. ADOT participation in this type of forum ensured that all aspects of each system's flow were accounted for including all internal and external interfaces.

Appendix I includes a management system summary, data flow tables and diagrams.

Executive Interviews

Executive input and support was recognized as an important factor in the success of any integration solution at ADOT. Interviews with key executives, along with their responses to published questionnaires, provided Marotz with valuable information to assist in formulating an appropriate plan for integration. ADOT executives were very forthcoming and helpful in identifying critical success factors, trends impacting goals, and potential barriers likely to affect the integration effort. Also discussed were unexpected benefits resulting from integration, how an integrated system might be used, type and form of information desired, and potential use and outcomes of this study.

Results of the executive interviews include the following key points:

Integration is expected to offer new opportunities and efficiencies although substantial cost savings do not appear likely primarily due to resource limitations.

There is a need for better performance metrics. Availability and use of measurement information must be carefully considered.

Integration should be small in scope, focused, and gradually implemented. Integration must be affordable using existing resources. Systems must be accessible in user friendly formats. Technical skill levels of potential users are limited.

A user accessible data dictionary would be of substantial benefit and would identify common data elements to avoid duplicates of systems/entries and would identify gaps in data.

A common desire amongst this group of ADOT representatives, was for development of a user accessible data dictionary which would identify common data elements to facilitate research efforts and maintenance (e.g. avoid duplicate systems/entries, identify gaps in data). Additionally, any initiatives to address this need were recommended to be low cost and low profile.

Commercial Data Warehouse Tools

Candidate data warehouse tools were identified, including two commercial products plus one which was developed internally by ADOT. Marotz sponsored half-day demonstrations of each of the two commercial tools selected at ADOT offices in October. Representatives from both Oracle Corporation and SHL Systemhouse provided presentations and written material describing their integrated transportation management systems for consideration by ADOT. Appendix III provides details regarding each of these systems.

A third demonstration was presented to the ADOT TAC members and Marotz representatives in January. ADOT's Transportation Planning Group, developers of the system, provided this presentation of the INFACCS system

The table that follows provides evaluation results for the Oracle, SHL and ADOT proposed solutions. Although the Oracle and SHL systems were impressive, INFACCS is clearly the superior solution for ADOT's needs. Criteria used to evaluate each system is detailed following the table.

Values: High – 3; Medium – 2; Low – 1 Evaluation Criteria

INFACCS	Oracle	SHL	
3	1	2	Incremental Procurement
3	1	2	Affordability
3	2	2	Tailored to ADOT Needs
3	2	2	Easy Data Access
3	1	2	Compatible with ADOT System Architecture (DBMS, hardware, etc.)
3	3	3	ISTEA Integration
1	3	1	Present Historical Data Logically
2	3	1	GIS Tie-In
2	3	3	Depth of Functionality
3	2	1	Development / Purchase Risk
2.6	2.1	1.9	Total Score

Evaluation criteria descriptions:

Incremental Procurement –

Can the software be purchased incrementally, allowing ADOT to migrate toward an ever more powerful system as funding is available and needs are more clearly defined? Incremental procurement allows ADOT to purchase the system gradually as funds are available.

Affordability –

Is the software affordable, including both the cost to procure and install the software itself and the cost for required upgrades to the ADOT infrastructure? Affordable systems are more clearly justified for the ADOT environment than extremely expensive systems.

Tailored to ADOT Needs –

Is the software easily tailored to specific ADOT needs? The software will better meet ADOT needs if it can be easily tailored.

Easy Data Access –

Can the data be easily viewed and manipulated by engineers and managers within ADOT? Ease of data access is one of the primary values of an integrated ISTEA system.

Compatible with ADOT System Architecture (DBMS, hardware, etc.) –

To what extent is the application compatible with existing ADOT architectural elements? Compatibility simplifies on-going system maintenance and training.

ISTEA Integration –

To what extent does the software fully integrate the various ISTEA management functions? The greater the degree of integration, the more powerful the decision support capabilities can be.

Present Historical Data Logically –

Can historical data be viewed intuitively? Viewing historical data can be useful in performing various types of analysis about historical trends.

GIS Tie-In –

What is the extent to which the software can be integrated with a Geographical Information System? Much of the ADOT desired functionality is best represented using a GIS.

Depth of Functionality –

What is the depth of analysis tools and other functionality included with the software? More functionality results in more powerful software.

Development / Purchase Risk –

What are the risks of project failure or other development/purchase problems. Lower risk projects are safer in terms of delivering on their promise.

INFACCS

INFACCS is being developed by ADOT's Transportation Planning Groupin response to requirements for a common ISTEA management reference system. Objectives of the project include: identification of data redundancy between management systems;

identification of duplicative data collection and storage effort; enhanced transportation planning through a technical architecture that will support query and reporting and seamlessly span multiple management systems. Planned completion of INFACCS is April of 1998. Following are some of the benefits that will be provided by this system:

- Literal end-user access to data and reports

- Integration non-standardized databases

- Existing systems shall remain the same

- Network load and server processing management

- Easy to maintain and administrate

- Does not affect the production environment

- Low risk investment and implementation

Additional details regarding INFACCS can be obtained from Micon, Inc.

DataFinder

The DataFinder program was developed by Marotz as a means of immediately addressing one of the deficiencies that has resulted from ISTEA non-integration: the need for a data dictionary. ADOT executives identified this same deficiency as an issue warranting attention during their interviews with Marotz. Data Finder is a data dictionary that finds and defines data elements existing within any one of the ADOT databases. Using DataFinder, an ADOT associate can search and determine the source or existence of specific system elements and/or descriptions as well as other element information.

Summary of Findings and Recommendations

ADOT's ISTEA and related systems contain a wealth of valuable information. However, lack of integration amongst these systems prevents ADOT from realizing the full value this data may provide if accessible to a wider audience. Integration is indeed a worthwhile goal and will undoubtedly enhance the effectiveness of the databases maintained by ADOT.

As a part of determining an appropriate integration strategy, it is important to consider the findings that resulted from executive surveys and interviews. A summary of key findings includes the following:

> Integration is expected to offer new opportunities and efficiencies although substantial cost savings do not appear likely primarily due to resource limitations.
>
> There is a need for better performance metrics. Availability and use of measurement information must be carefully considered.
>
> Integration should be small in scope, focused, and gradually implemented. Integration must be affordable using existing resources. Systems must be accessible in user friendly formats. Technical skill levels of potential users are limited.
>
> A user accessible data dictionary would be of substantial benefit and would identify common data elements to avoid duplicates of systems/entries and would identify gaps in data.

Based upon our research and understanding of ADOT resources and needs, it is our recommendation that ADOT pursue development and implementation of the INFACCS system (database link) to achieve the goal of data integration. Although in its early stages it was uncertain as to whether this system would meet ADOT's integration needs, INFACCS has made great advances in the directions necessary to resolve integration issues. This system has been demonstrated to the satisfaction of Marotz and ADOT TAC members and has earned the support of both groups.

Resources

ADOT Documents

ADOT Technical Information Resources Three Year Plan 1996-1998
Micon Inc. Executive Presentation 8/1/96
Strategic Plan for ITS Communications
Arizona State Transportation Plan 12/94
Lima and Associates diagrams (2 pg.)
HPMS ESAL report samples (4 pg.)
HPMS Field Manual 8/30/93 and 4/22/94
State Bridge Inventory System (SBIS) Guide 10/91
Safety Management System Work Plan 7/1/94
CLOSE with ALISS 2/88
ATIS News 7/30/96
ISTEA/Data Coordination Project, Final Report 7/95
Draft YMPO 1995 Congestion Management Report
Maintenance Management Table of Contents for Rating Criteria Sheets (3 pgs)
PTMS Transportation Management System, 2/95
Public Transportation Management System (PTMS), Phase Two Strategic Options 3/96
PTMS Report and Database User's Manual, 9/95
PAG 1992, Mobility Management Plan, Summary Plan
Draft Final Report, Congestion Management System
Congestion Management System, Fiscal Year 1995
Intermodal Transportation Division, Data Elements
Intermodal, Traffic Engineering Group, Data Elements
Lee Engineering, CMS Link File Description (2 pgs)
Pavement Structure for Table
Pecos Data Elements
National Bridge Inventory Record Format

ADOT Associates

The following ADOT associates played a valuable role in contributing to this study. Their genuine interest, forthright manner, consideration and support in providing assistance was greatly appreciated.

Name	Title or Department	Role in Study
Dell Beesley	Five Year Plan	Technical Advisory Committee
Larry Bonine	Director	Executive interviewee
Wes Bowling	Five Year Plan	Participated in initial interview and information gathering

Name	Title or Department	Role in Study
		process
Dale Buskirk	Intermodal Management	Participated in initial interview and information gathering process
Ron Chubb	Maintenance Management	JAD attendee
Murray Collon	Maintenance Planning Services, EDP Supervisor	JAD attendee
Wayne Collins	Intermodal Transportation Division, Deputy State Engineer	Executive interviewee
Dan Davis	Bridge	JAD attendee
Jim Delton	Pavement Management	Project Manager; participated in initial interview and information gathering process; JAD attendee; participated in evaluation of DataFinder
Jim Dorre	Maintenance Management	Participated in initial interview and information gathering process; evaluated DataFinder
David Duffy	Traffic Engineering	JAD attendee
Tony Gonzales	GIS	Participated in initial interview and information gathering process
August Hardt	Assistant State Engineer	Executive interviewee
Ken Howell	Congestion Management (Lee Engineering)	Participated in initial interview and information gathering process
Glenn Jonas	FMS	JAD attendee
Charles Jones	PPMS	JAD attendee
Hari Khana	Project Scheduling	Participated in initial interview and information gathering process
Greg Kiely	Public Transit Management	Participated in initial interview and information gathering process; JAD attendee
Jay Klagge	Transportation Planning	Executive interviewee
Cheryl Egland	Engineering	DataFinder evaluation
John Louis		Technical Advisory Committee, DataFinder evaluation
Mike Manthey	Safety Management & ALISS	Participated in initial interview and information gathering process; JAD attendee; participated in evaluation of DataFinder
Joe O'Neill	Equipment Services	Executive interviewee
Mary Peters	Deputy Director	Executive interviewee

Name	Title or Department	Role in Study
Bob Pike	Traffic Monitoring & HPMS	Participated in initial interview and information gathering process; JAD attendee
Thalia Pratt	Public Transit Management	JAD attendee
Wayne Rich	GIS Mapping	JAD attendee
Suzanne Sale	Administrative Services	Executive interviewee
Bill Sapper	Public Transit Management	JAD attendee
Tom Schmitt	State Engineer	Executive interviewee, DataFinder evaluation
John Semmens	Intermodal Transportation Division, Senior Planner	Project Manager DataFinder installation
Jim Shea	Freeway Management	Participated in initial interview and information gathering process
Katie Underwood-Murphey	Chief Information Officer, Technical Information Resources	Executive interviewee
Tim Wolfe	Intelligent Highway	Participated in initial interview and information gathering process
Pe-Shen Yang	Bridge Management	Participated in initial interview and information gathering process; JAD attendee

Commercial Resources

Technical presentations of commercial data warehouse tools for transportation management systems were provided at ADOT by:

Oracle Corporation
SHL Systemhouse Inc.

Other Resources

A presentation of ADOT's PMIS integration plan was provided during the January TAC meeting by Dell Beesley and Wes Bowling.

Appendices

Appendix I	Glossary
Appendix II	Management System Summary Table and Data Flow Tables and Diagrams
Appendix III	Oracle Transportation
Appendix IV	SHL Infrastructure Management System
Appendix V	DataFinder User's Manual

Appendix I

Glossary

Glossary

	Definition
ADOT	Arizona Department of Transportation
ALISS	Accident Location Identification and Surveillance System, safety management system
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CLOSE	Locates candidate locations for operational evaluations
COG	Council of Government
CMS	Congestion Management System consists of information based on the identification of congested facilities and mobility conditions
EMS	Equipment Management System
FHWA	Federal Highway Authority
FMS	Freeway Management System maintains records of district road conditions and traffic volumes
HPMS	Highway Performance Management System consists of historical information that represents travel estimates for the National Highway System
IMS	Intermodal Management System consists of information based upon the convenient intermodal movement of people and goods through the integration of transportation facilities and systems
ISTEA	Intermodal Surface Transportation Efficiency Act
MAG	Metropolitan Association of Governments
MPO	Metropolitan Planning Organization
NBI	National Bridge Inventory
PECOS	Maintenance management system tracks maintenance of pavement, ditches, fences, (not buildings), interstate, rest areas, landscaping, paint stripes, ramps, lots.
PMIS	Project Management Information System tracks information resource data, geographical locations, project tracking data, comments, cost estimates and actuals, additional planning data (projections for completion dates)
PMS	Pavement Management System is a historical information repository of pavement conditions and characteristics
PONTIS	Performs economic forecasting, planning and project maintenance scheduling
Project Scheduling	Maintains an overview of projects ad their scheduling status and cost
PTMS	Public Transit Management System
RPTA	Regional Public Transit Authority
SBIS	State Bridge Inventory System tracks information about state bridges as dictated by the NBI
SMS	Safety Management System (ALISS)
SIA	Structural Inventory and Appraisal Sheets
TAC	Technical Advisory Committee
TMS	Traffic Management System

	Definition
TPG	Transportation Planning Group

Appendix II

Management System Summary Table

Data Flow Tables and Diagrams

Management System Summary

ISTEA MANAGMENT	SYSTEM	DESCRIPTION	AUTOMATION
Bridge	SBIS State Bridge Inv PONTIS	SBIS (State Bridge Inventory System) tracks information about state bridges dictated by the NBI (National Bridge Inventory). PONTIS will perform economic forecasting, planning and project maintenance scheduling.	PC based Borland Dbase IV PC based mult serv
Pavement	PMS Pavement Mgmt Sys	PMS is a historical information repository of pavement conditions and characteristics.	Four Microsoft Foxpro databases
Safety	ALISS Accident Location Identification & Surveillance	ALISS is a historical repository of information pertaining to accidents. CLOSE program locates candidate locations for operational evaluations.	Sun/PC environment using Sybase database software. Core of ALISS is UNIX-based Geographical Information System, GIS, developed with ESRI's ARC/INFO and ARCVIEW software components.
Public Transit	PTMS Public Transp. Facilities & Equip.	PTMS is used to manage conditional and descriptive information of both vehicle and facility type assets which fall under the Public Transportation classification.	Microsoft Foxpro
Intermodel	IMS	Intermodal system consists of information based upon the convenient intermodal movement of people and goods through the integration of transportation facilities and systems.	Microsoft Access integrated w/Mapinfo GIS software
Congestion	CMS	Congestion consists of information based on the identification of congested facilities and mobility conditions.	Quatro spreadsheet
	HPMS Highway Performance Monitoring	HPMS consists of historical information which represents travel estimates for the National Highway System.	Microsoft Foxpro
	PMIS 5 Year Plan Project Mgmt. Info. Sys.	PMIS tracks information resource data, geographical locations, project tracking data, comments, cost estimates and actuals, additional planning data (projections for completion dates).	
	FMS Freeway	FMS maintains records of district road conditions and traffic volumes.	Sybase Sun Unix

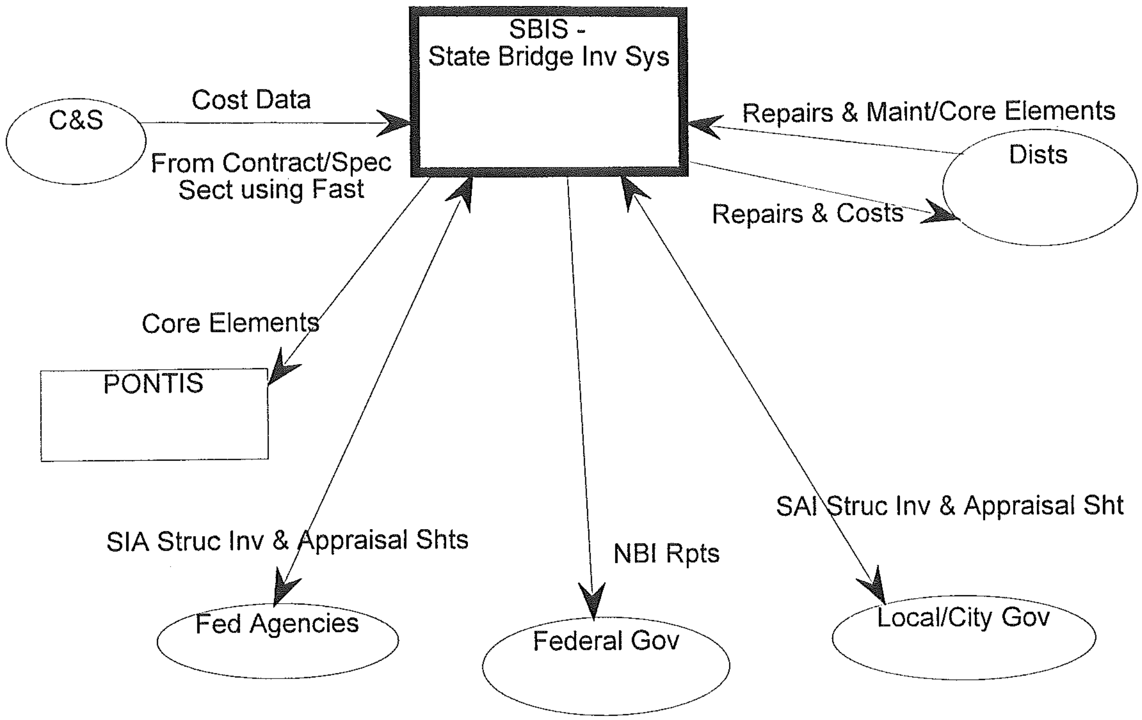
ISTEA MANAGMENT	SYSTEM	DESCRIPTION	AUTOMATION
	PECOS Maintenance Mgmt. Sys.	Tracks maintenance of pavement, ditches, fences, (no buildings), interstate, rest areas, landscaping, paint stripes, ramps, lots.	Pecos II dbase & mainframe (IMS)
	Project Scheduling	Maintains overview of projects and their scheduling status and cost.	Primavera/Artemis

SBIS

State Bridge Inventory System

The State Bridge Inventory System, SBIS, tracks information about state bridges as dictated by the National Bridge Inventory, NBI. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Cost Data from contract specialists using FAST	
	Core elements to PONTIS
SIA structure inventory and appraisal sheets from federal agencies	SIA structure inventory and appraisal sheets to federal agencies
	NBI reports to federal government
SAI structure inventory and appraisal sheets from local and city government	SAI structure inventory and appraisal sheets to local and city government
	Repairs and costs to districts
Repairs and maintenance/core elements from districts	

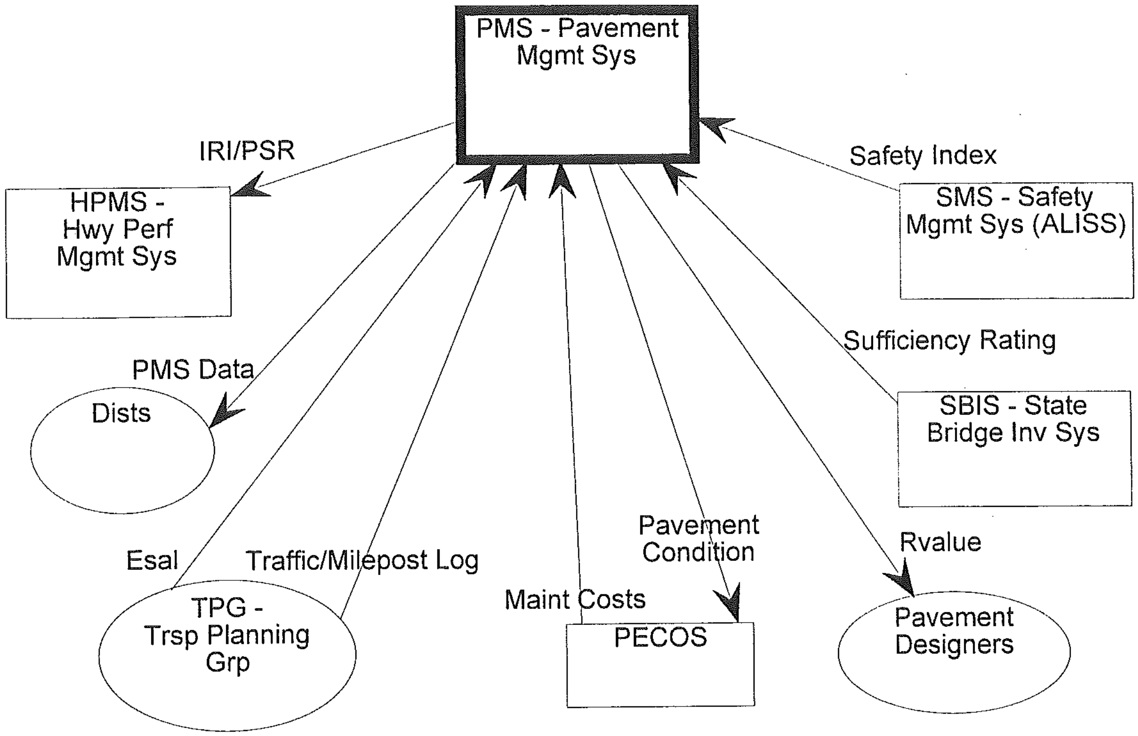

SBIS -
State Bridge Inv Sys
C&S
Cost Data
From Contract/Spec
Sect using Fast
Repairs & Maint/Core Elements
Dists
Repairs & Costs
Core Elements
PONTIS
SIA Struc Inv & Appraisal Shts
NBI Rpts
SAI Struc Inv & Appraisal Sht
Fed Agencies
Federal Gov
Local/City Gov

PMS

Pavement Management System

The Pavement Management System, PMS, is a historical information repository of pavement conditions and characteristics. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
	IRI/PSR to HPMS
	PMS data to districts
Esal data from TPG	
Traffic/milepost log from TPG	
Maintenance costs from PECOS	
	Pavement condition to PECOS
	R value to pavement designers
Sufficiency rating from SBIS	
Safety index from SMS	



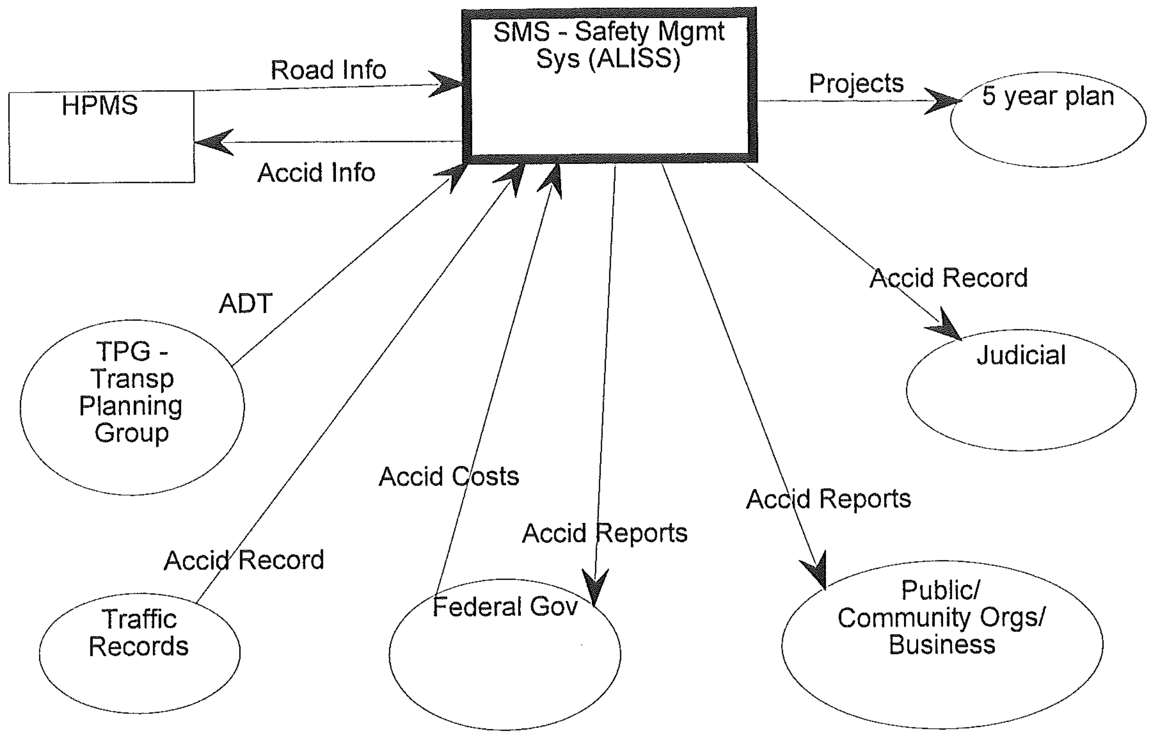
PMS - Pavement Mgmt Sys
IRI/PSR
HPMS - Hwy Perf Mgmt Sys
Safety Index
SMS - Safety Mgmt Sys (ALISS)
Sufficiency Rating
SBIS - State Bridge Inv Sys
PMS Data
Dists
Esal
Traffic/Milepost Log
TPG - Trsp Planning Grp
Pavement Condition
Maint Costs
PECOS
Rvalue
Pavement Designers

ALISS

Accident Location Identification and Surveillance System

The Accident Location Identification and Surveillance System, ALISS, is a historical repository of information pertaining to accidents. The CLOSE program locates candidate locations for operational evaluation. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Road information from HPMS	
	Accident information to HPMS
ADT from TPG	
Accident records from traffic records	
Accident costs from federal government	
	Accident reports to federal government
	Accident reports to public, community organizations, businesses
	Accident records to judicial
	Projects to five year plan

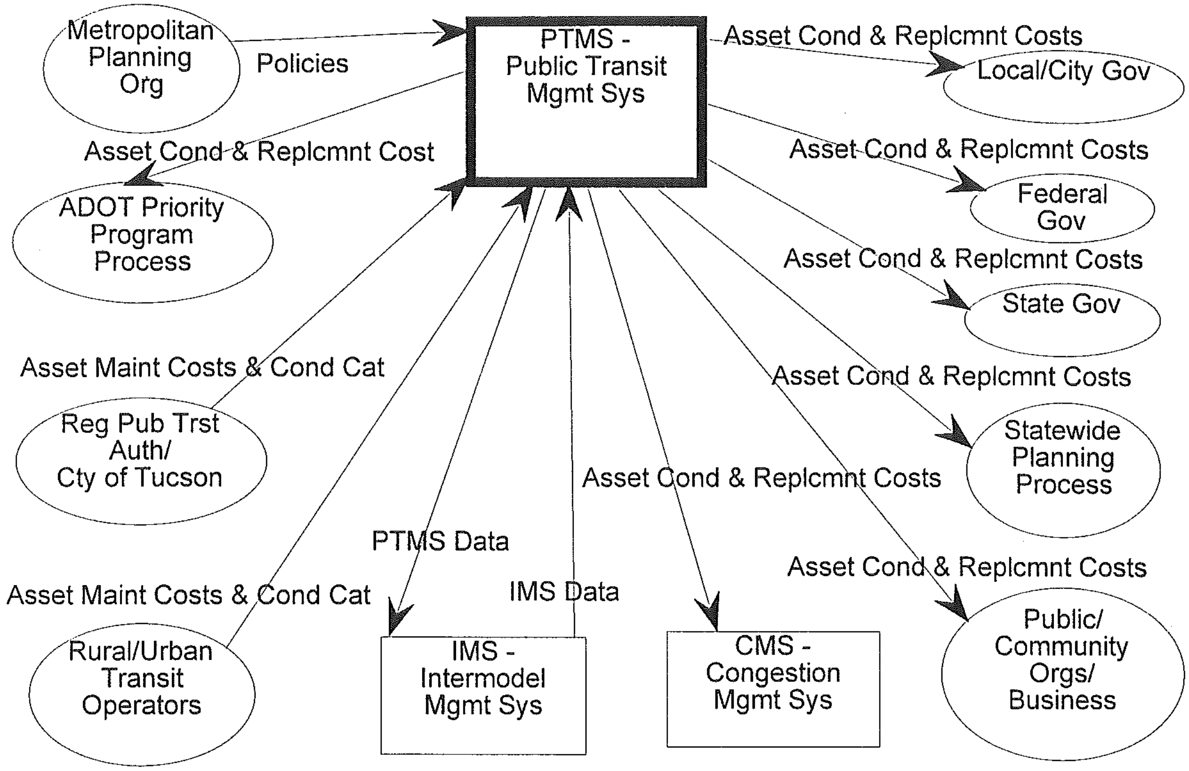

SMS - Safety Mgmt Sys (ALISS)
HPMS
Road Info
Accid Info
Projects
5 year plan
ADT
TPG - Transp Planning Group
Accid Record
Judicial
Accid Costs
Accid Reports
Accid Reports
Accid Record
Traffic Records
Federal Gov
Public/ Community Orgs/ Business

PTMS

Public Transit Management System

The Public Transit Management System is used to manage conditional and descriptive information of both vehicle and facility type assets which fall under the Public Transportation classification. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Policies from MPO	
	Asset conditions and replacement costs to priority program process
Asset maintenance costs and conditions categories from regional public transit authority and rural/urban transit operators	
	PTMS data to IMS
IMS data from IMS	
	Asset condition and replacement costs to CMS, public, community organizations, businesses, statewide planning process, state/federal/local/city government



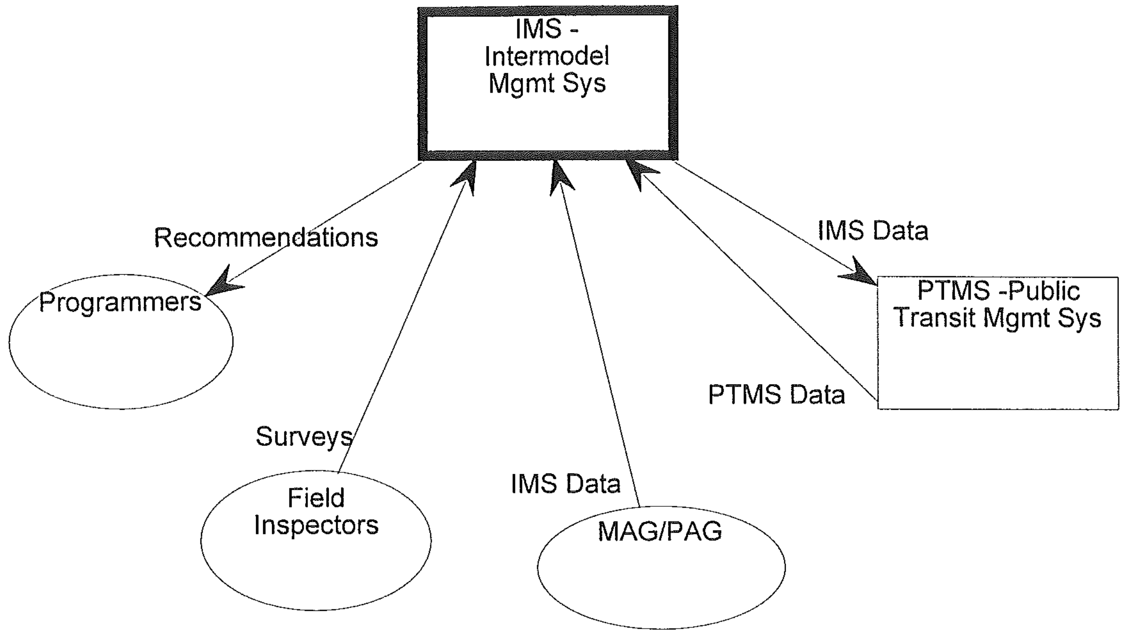
Metropolitan Planning Org
Policies
PTMS - Public Transit Mgmt Sys
Asset Cond & Replcmnt Costs
Local/City Gov
Asset Cond & Replcmnt Cost
ADOT Priority Program Process
Asset Cond & Replcmnt Costs
Federal Gov
Asset Cond & Replcmnt Costs
State Gov
Asset Maint Costs & Cond Cat
Reg Pub Trst Auth/ Cty of Tucson
Asset Cond & Replcmnt Costs
Statewide Planning Process
Asset Cond & Replcmnt Costs
PTMS Data
Asset Cond & Replcmnt Costs
Asset Maint Costs & Cond Cat
IMS Data
Rural/Urban Transit Operators
IMS - Intermodel Mgmt Sys
CMS - Congestion Mgmt Sys
Public/ Community Orgs/ Business

IMS

Intermodal Management System

The Intermodal Management System, IMS, consists of information based upon the convenient intermodal movement of people and goods through the integration of transportation facilities and systems. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
	Recommendations to programmers
Surveys from field inspectors	
IMS data from MAG/PAG	
PTMS data from PTMS	
	IMS data to PTMS

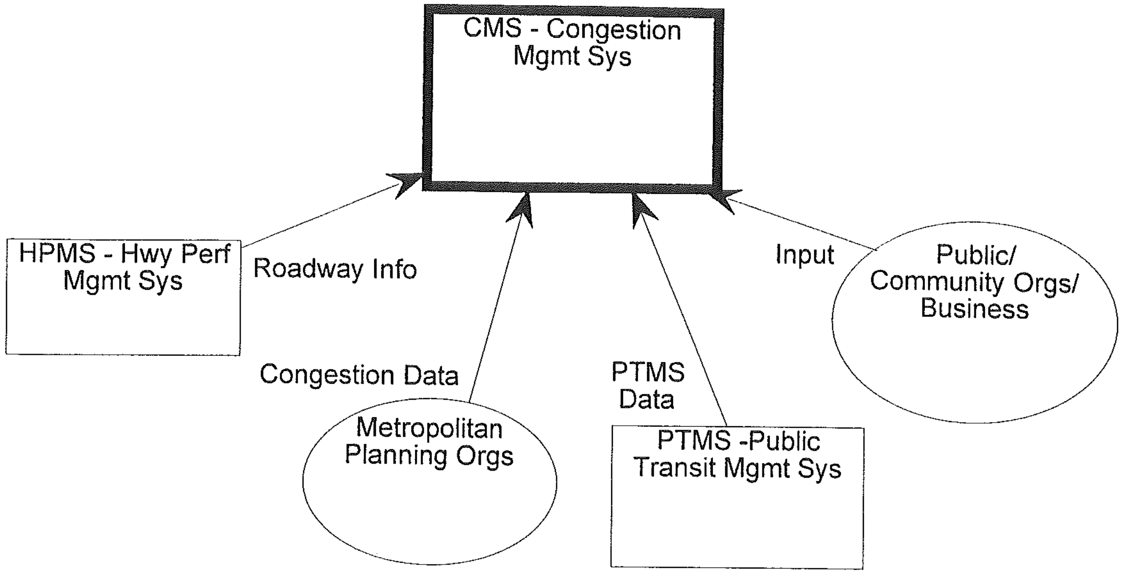

IMS -
Intermodel
Mgmt Sys
Recommendations
Programmers
IMS Data
PTMS -Public
Transit Mgmt Sys
PTMS Data
Surveys
Field
Inspectors
IMS Data
MAG/PAG

CMS

Congestion Management System

The Congestion Management System, CMS, consists of information based on the identification of congested facilities and mobility conditions. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Roadway information from HPMS	
Congestion data from MPO	
PTMS data from PTMS	
Input from public, community organizations, businesses	



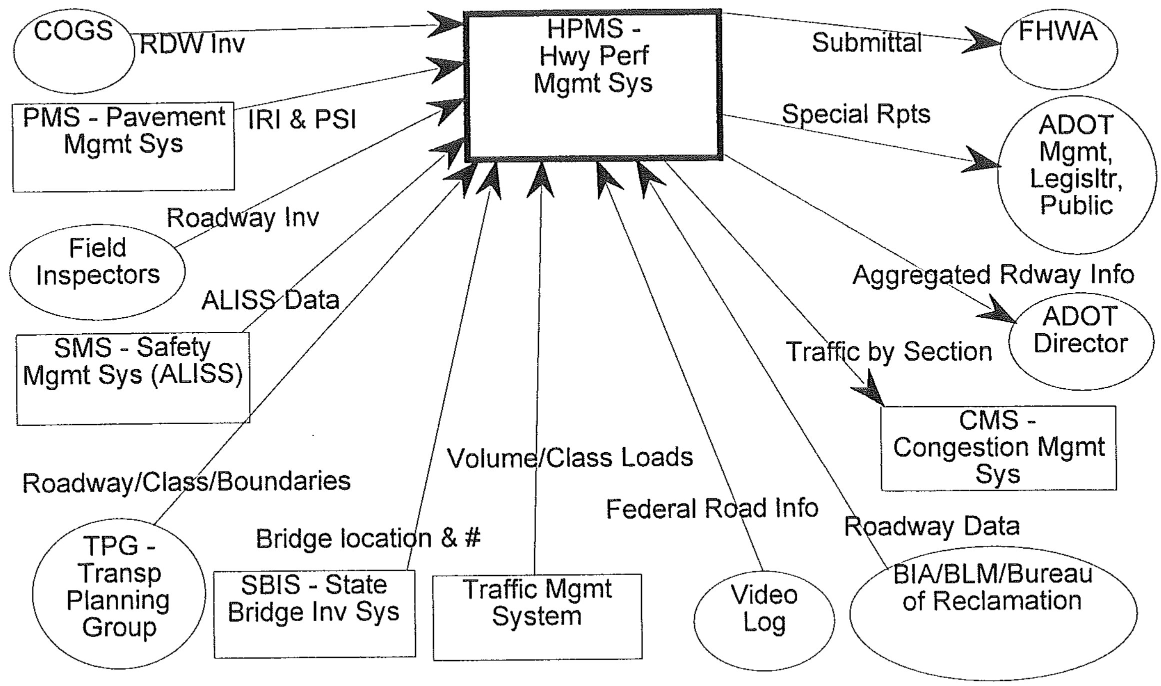
Future plans include rating information from BMS, SMS, IMS, PMS and from non-urban COGs such as Ctrl AZ Assoc of Gov (CAAG), N AZ Council of Gov (NACOG), SE AZ Gov Org (SEAGO), W AZ COG (WACOG).

HPMS

Highway Management System

The Highway Management System, HPMS, consists of historical information that represents travel estimates for the National Highway System. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
RDW from COGS	
IRI and PSI from PMS	
Roadway Inventory from field inspectors	
ALISS data from ALISS	
Roadway, class, boundaries from TPG	
Bridge location and number from SBIS	
Volume/class loads from TMS	
Federal road information from video log	
Roadway data from BIA/BLM/Bureau of Reclamation	
	Traffic by section to CMS
	Aggregated roadway information to ADOT director
	Special reports to ADOT management, legislators, public
	Submittal to FHWA

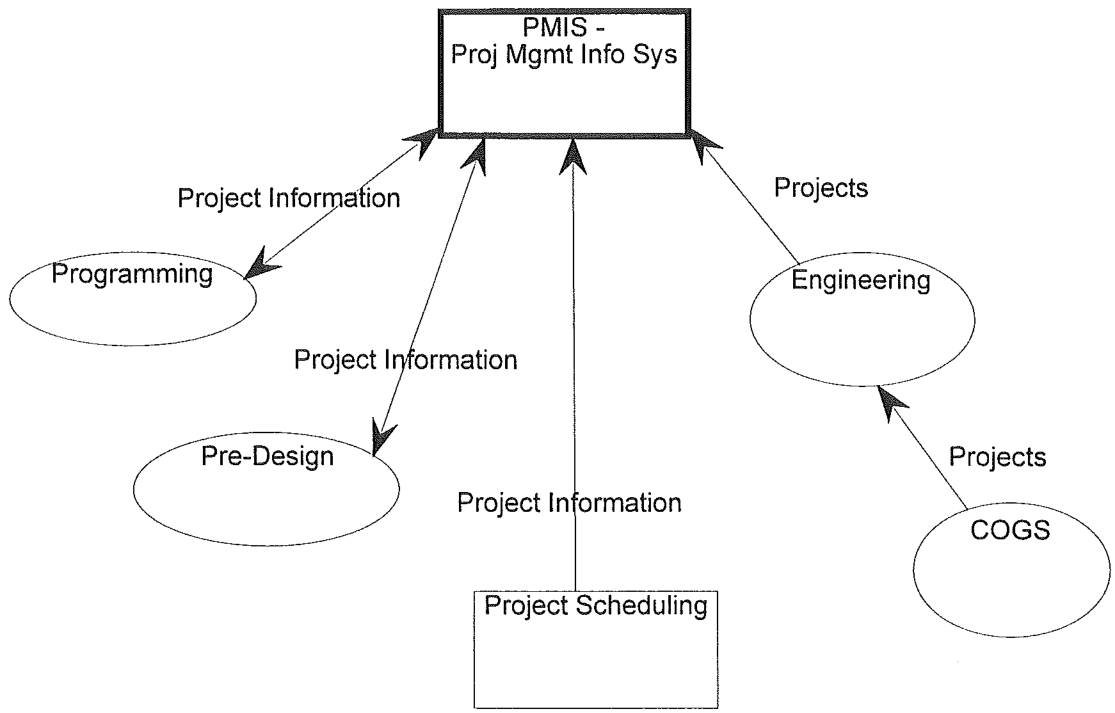

COGS
RDW Inv
HPMS - Hwy Perf Mgmt Sys
Submittal
FHWA
PMS - Pavement Mgmt Sys
IRI & PSI
Special Rpts
ADOT Mgmt, Legisltr, Public
Roadway Inv
Field Inspectors
Aggregated Rdway Info
ADOT Director
ALISS Data
SMS - Safety Mgmt Sys (ALISS)
Traffic by Section
CMS - Congestion Mgmt Sys
Volume/Class Loads
Roadway/Class/Boundaries
Federal Road Info
Roadway Data
Bridge location & #
TPG - Transp Planning Group
SBIS - State Bridge Inv Sys
Traffic Mgmt System
Video Log
BIA/BLM/Bureau of Reclamation

PMIS

Project Management Information System

The Project Management Information System, PMIS, tracks information resource data, geographical locations, project tracking data, comments, cost estimates and actuals, additional planning data (projections for completion dates). Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Project information from programming and pre-design	Project information to programming and pre-design
Project information from project scheduling	
Projects from engineering (originating from COGS)	

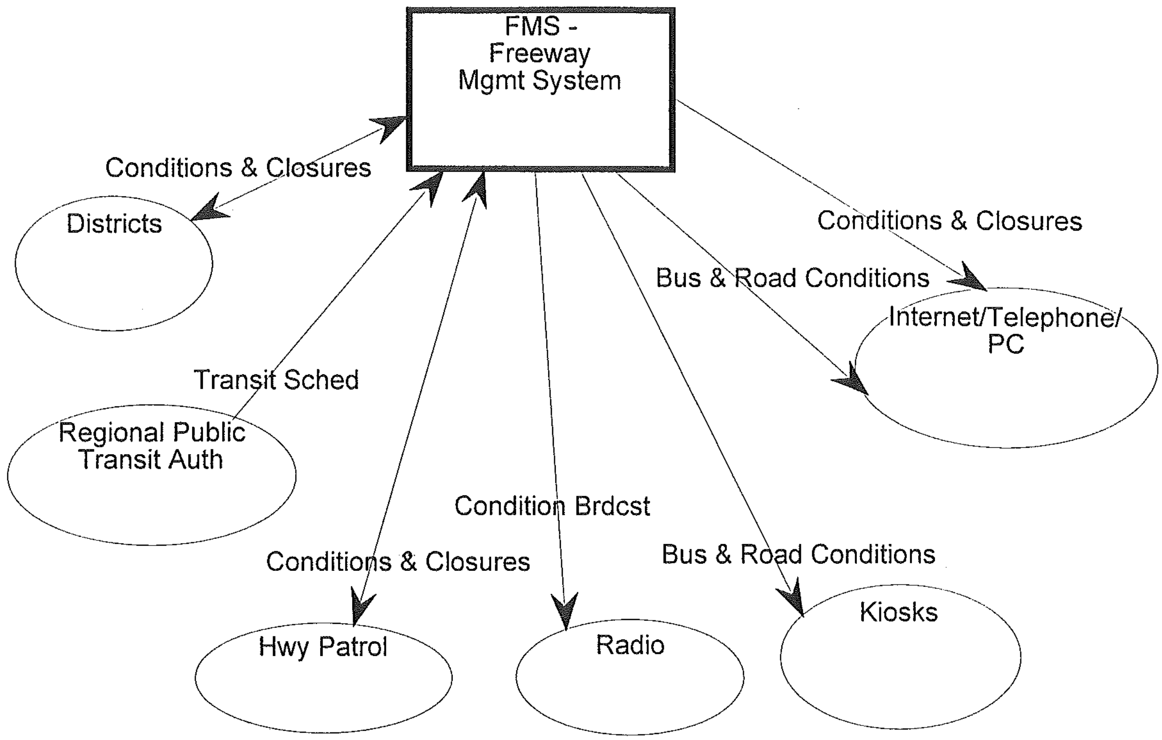

PMIS -
Proj Mgmt Info Sys
Project Information
Programming
Project Information
Pre-Design
Project Information
Project Scheduling
Projects
Engineering
Projects
COGS

FMS

Freeway Management System

The Freeway Management System, FMS, maintains records of district road conditions and traffic volumes. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Conditions and closures from districts and highway patrol	Conditions and closures to districts and highway patrol
Transit schedule from regional public transit authority	
	Condition broadcast to radio
	Bus and road conditions to kiosks, internet, telephone, PC
	Conditions and closures to internet, telephone, PC

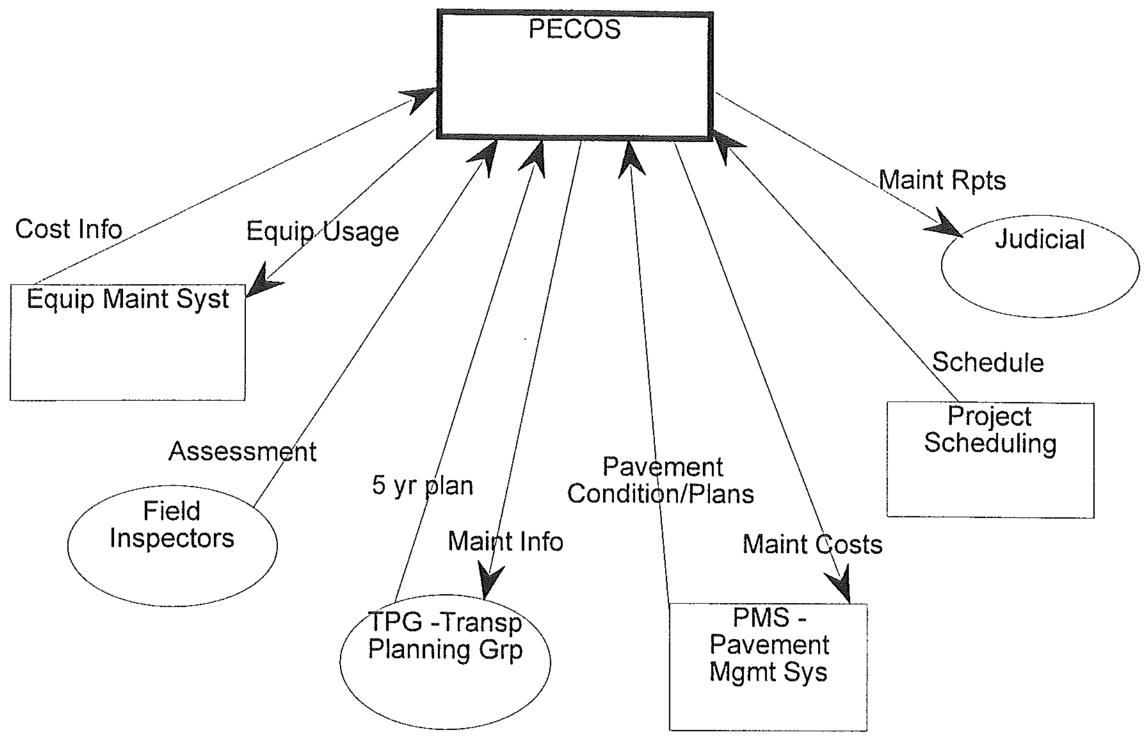

FMS -
Freeway
Mgmt System
Conditions & Closures
Districts
Transit Sched
Regional Public
Transit Auth
Conditions & Closures
Hwy Patrol
Condition Brdcst
Radio
Bus & Road Conditions
Kiosks
Conditions & Closures
Bus & Road Conditions
Internet/Telephone/
PC

PECOS

PECOS Maintenance Management System

The PECOS Maintenance Management System tracks maintenance of pavement, ditches, fences, (not buildings), interstate, rest areas, landscaping, paint stripes, ramps, lots. Data flow is summarized in the following table and diagram.

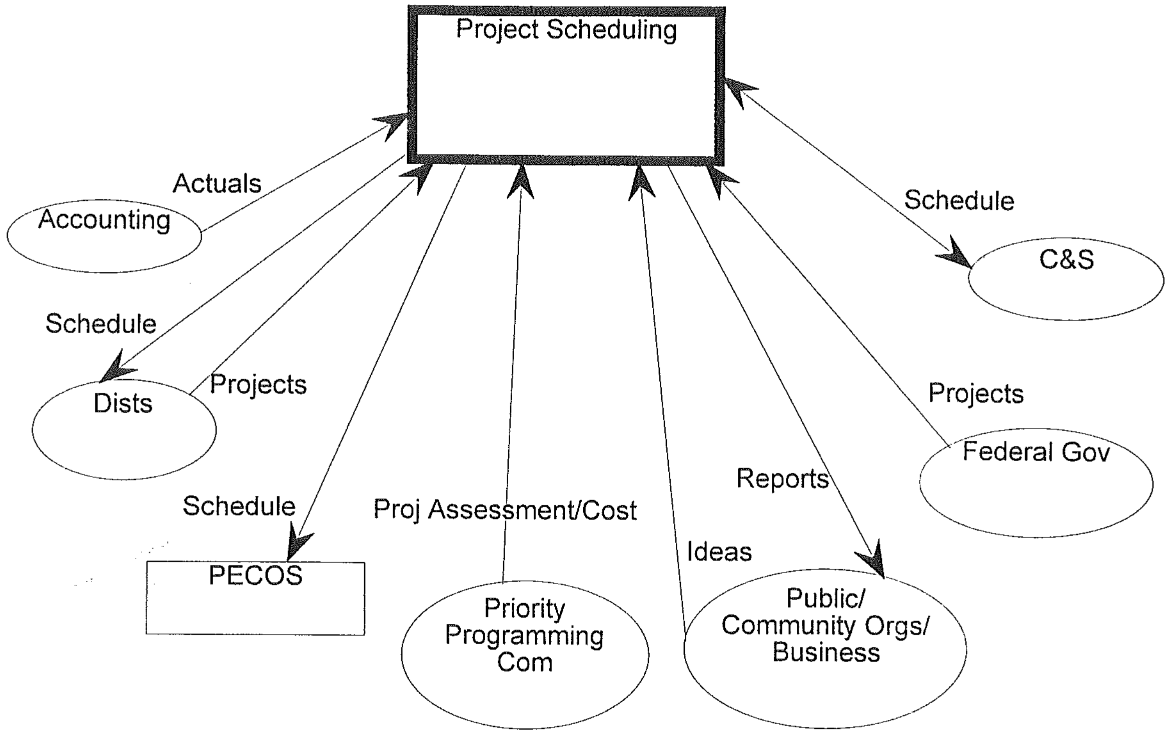
Incoming Data Flow	Outgoing Data Flow
Cost information from EMS	
	Equipment usage to EMS
Assessment information from field inspectors	
5 year plan from TPG	
	Maintenance information to TPG
Pavement condition and plans from PMS	
	Maintenance costs to PMS
Schedule from project scheduling	
	Maintenance reports to judicial


PECOS
Cost Info
Equip Usage
Maint Rpts
Judicial
Equip Maint Syst
Schedule
Project Scheduling
Assessment
5 yr plan
Pavement Condition/Plans
Field Inspectors
Maint Info
Maint Costs
TPG -Transp Planning Grp
PMS - Pavement Mgmt Sys

Project Scheduling System

The Project Scheduling System maintains an overview of projects and their scheduling status and cost. Data flow is summarized in the following table and diagram.

Incoming Data Flow	Outgoing Data Flow
Actuals from accounting	
	Schedule to districts
Projects from districts	
	Schedule to PECOS
Project Assessment and cost from priority programming committee	
Ideas from public, community organizations, businesses	
	Reports to public, community organizations, businesses
Projects from federal government	
Schedule from C & S	Schedule to C & S

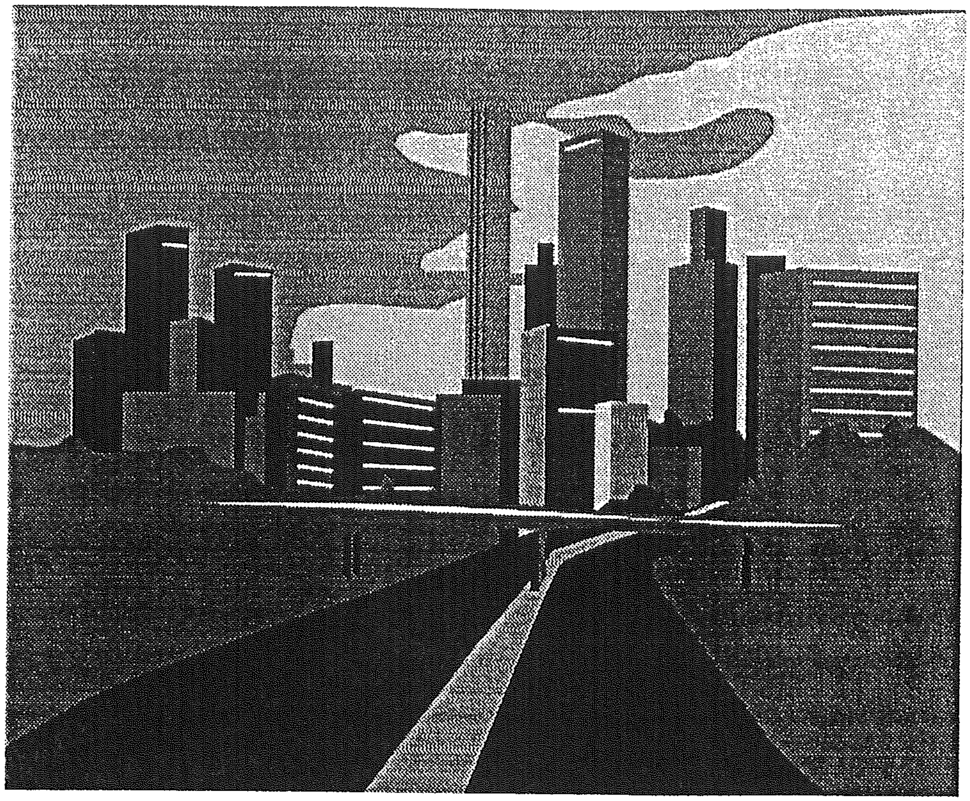

Project Scheduling
Actuals
Accounting
Schedule
C&S
Schedule
Dists
Projects
Projects
Federal Gov
Reports
Schedule
Proj Assessment/Cost
Ideas
PECOS
Priority Programming Com
Public/ Community Orgs/ Business

Appendix III

Oracle Transportation Manager

ORACLE

Oracle Corporation
8800 Cal Center Drive
Suite 300
Sacramento
California 95826
phone 916.366.0792
fax 916.366.3051



Oracle Transportation Manager

The Solution of Choice

Oracle Transportation Manager

Oracle Transportation Manager (OTM), is an *Enterprise Solution Enabler* developed by Oracle Corporation specifically to meet the needs of public and private transportation agencies. This application maintains the core information on the various types of transportation networks and provides for the integrated storage of data on the related infrastructure. OTM provides the flexibility to manage not only a highway network, but also rail, bus, waterway, pipeline, and utility line networks. OTM meets the needs of Transportation Agencies and takes advantage of the latest hardware and software technologies.

OTM combines the latest computer technology, a base of transportation clients, and a team of Oracle's Transportation Specialists, resulting in the application solution for diverse Transportation Agencies worldwide

The OTM Solution

OTM was developed to address the particular needs of the transportation industry. OTM, as preconfigured and setup, manages a core set of data items relating to the transportation network. It has been designed so that it can be configured to address the specific inventory data needs of individual clients. This configuration effort is accomplished through the use of OTM's existing tables and Oracle's CASE products.

The inherent features of the system allow the product to be used successfully worldwide, by a variety of agencies with differing needs, without modifying the base source code. Therefore, agencies do not need to employ large programming staffs to maintain the application system. In addition, Oracle Services has dedicated development and maintenance consulting groups that can assist with the implementation of OTM.

Industries Served by Oracle Transportation Manager

The transportation industry can be defined as any agency or corporation that needs to manage a network that transports people or goods. The OTM product has been developed to satisfy the diverse yet common needs of the transportation industry. The following are a few examples where OTM can be used:

- Highway Systems
- Street Systems
- Railway Systems
- Waterway Systems
- Utilities

The product allows management of one or more modes of transportation supporting multi-modal systems. OTM allows the establishment of multiple transportation networks within the data base. For each network, it maintains the individual routes, their history, and their connectivity to one another. It then provides the means by which the various types of infrastructure inventory used on the different types of networks are recorded and retrieved.

The OTM Vision

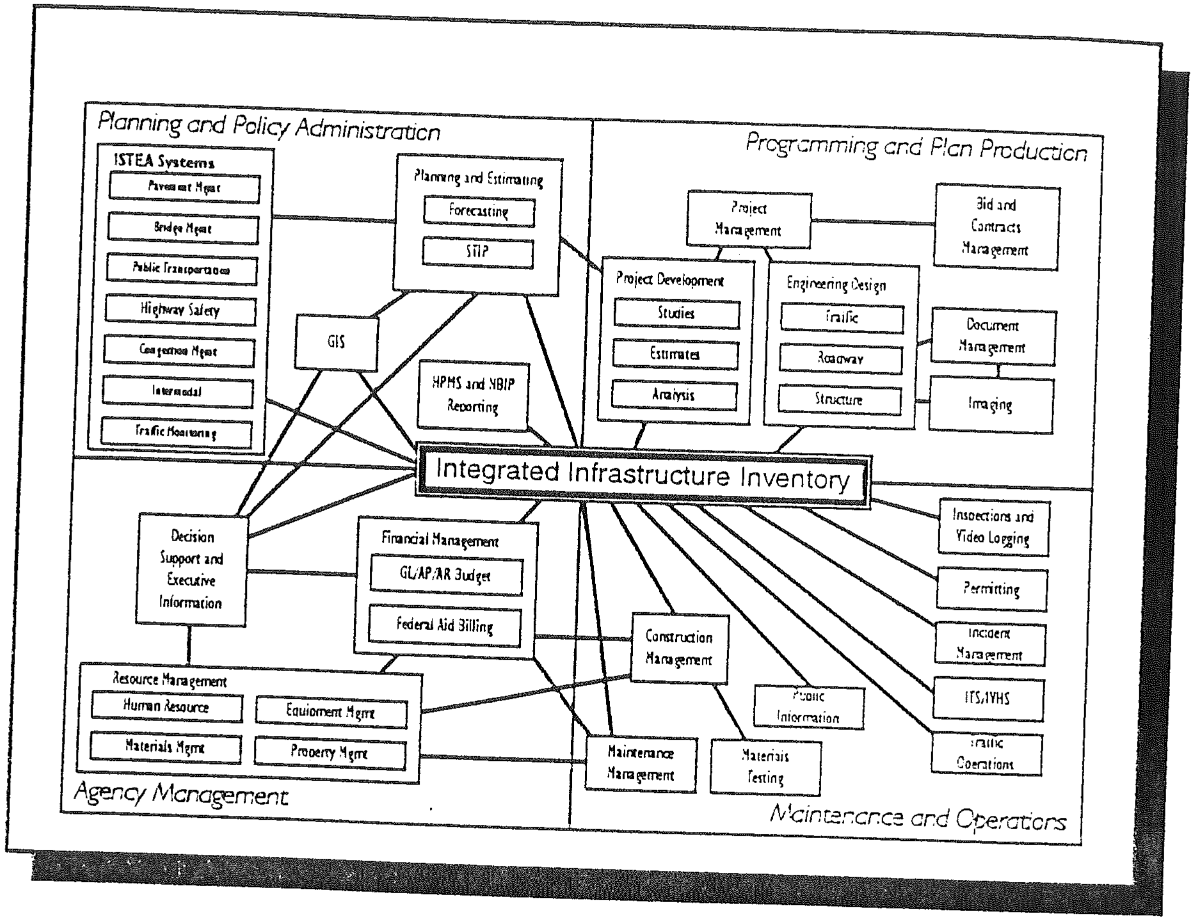
Transportation agencies are large and complex entities made up of numerous discrete units. All to often, the business processes of these units extend only to the limits of their own responsibilities. As a result, they have tended to act independently of each other. In particular, the development of automated systems has typically been constrained to only the information that the unit itself required.

However, transportation agencies as a whole are now beginning to take a longer and wider view of their business processes. They recognize that the independence of the individual units has led to the creation of equally independent computer systems forming "information islands" within the agency. Unfortunately, since these systems were developed with a narrow focus, it is often difficult, and in some cases impossible, to assemble information concerning the same physical facility from the disparate sources.

Our approach in developing Oracle Transportation Manager was to look at the transportation agency as a single business entity with many separate but related needs. We began by recognizing that the "information islands" all contained a single common element; the transportation network. No matter what information was being gathered or created, it all, in one way or another, had to be equated to one or more locations on the network. Therefore, we undertook to design OTM using the concept of the transportation network as the core element of an enterprise-wide solution enabler for transportation agencies. Around this core could then be built the various applications needed by the individual units within the agencies.

In our vision, the Information Structure of a typical transportation agency can be viewed as an interconnected set of applications with the integrated infrastructure inventory at the center. This vision is illustrated by the following diagram which shows the typical types of information systems found in a state department of transportation.

Transportation Department Information Structure



With this image in mind, we then decided on the key objectives of the system design. These can be summarized as follows:

1) The scope of the system would be *transportation*, not just highways. As the successor to the Oracle*Highways product, we recognized the reality that transportation agencies are no longer solely in the business of building roads. Rather, they are now responsible for entire transportation systems that can include multiple modes. Thus, OTM would have the ability to concurrently accommodate multiple modal networks as well as the intermodal relationships between networks.

2) The system must be capable of utilizing multiple linear referencing methods simultaneously. Although virtually all transportation agencies use linear referencing to locate items on the networks, they do not all use the same methods. In fact, it is not uncommon to find multiple referencing methods being used within the same agency. For this reason, OTM would be designed to permit the creation and use of multiple alternate referencing systems.

3) The product should allow the use of both the English and metric systems of measurement. The drive toward metrication of the transportation industry was fully underway at the time OTM was being conceived. For this reason, OTM would be designed to accommodate either or both systems. In OTM, attribute and location data can be entered or viewed in either system based on the user's preference. It is stored in the system units established by the client at the time OTM is configured.

4) OTM must maintain temporal (date) information about both the network and the inventory. We recognized that transportation networks are not static. They grow and change frequently. Because of this, agencies must be able to determine not only the current network and inventory status, but also what it was at a given point in time, past or future. OTM, therefore, would be designed to date stamp the data records.

5) The system should incorporate the principals of dynamic segmentation. The storage of information about the network should reflect the actual physical conditions without the need for artificial break points. For example, if a road is paved with concrete across multiple counties, the system must allow a single pavement data record to be created that includes the beginning and ending points of the concrete pavement. The user should not be required to create multiple records simply because the road crosses a county line.

6) The product must utilize the full power of the latest Oracle technology. This includes:
    a) The use of Oracle's CASE products (Designer/2000™ and Developer/2000™) for the creation of both OTM Core and user application modules
    b) Creation of a Graphical User Interface with Oracle Forms 4.5™
    c) Allowing a true relational data structure in Oracle 7™ which can be defined by the client.

Having established the vision and objectives for Oracle Transportation Manager, we proceeded to design and create a system that would realize these high goals.

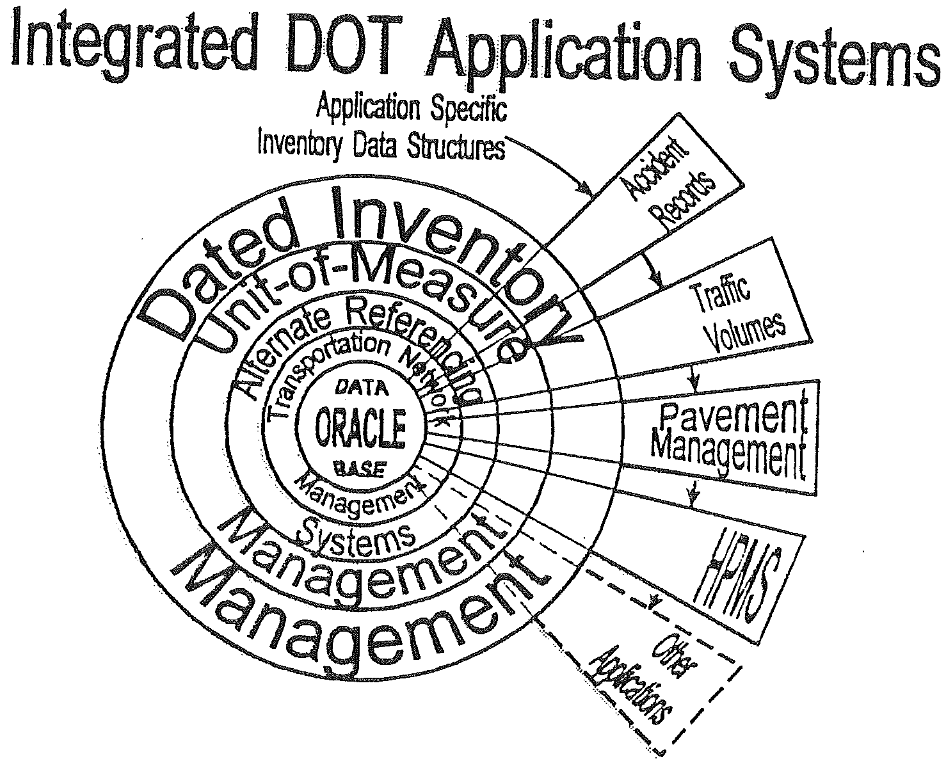
OTM Product Architecture

OTM has been developed to overcome the problems that result from most legacy systems in transportation agencies. These systems have been developed over time and were usually created for a specific purpose. Consequently, many functions are duplicated across the systems consuming valuable resources. Compounding the situation are instances when the data is referenced in different manners resulting in a situation where the information can not be compared between functional areas.

In examining legacy systems, such as pavement management, accident records, and traffic volumes, it is apparent that each maintains different information. Their common thread, however, is that each of them has some representation of the underlying transportation network. The difficulty is that frequently these representations are not compatible or synchronized with each other. This makes the cross-retrieval of information labor-intensive and time-consuming at best and impossible at worst.

OTM takes an alternate approach, as shown in the following diagram, of building the transportation network representation at the core of the system and allowing the functional applications to be "plugged into" this core. In this manner, all of the functional applications share the same representation of the transportation network simplifying the cross-correlation of the data.

The diagram below illustrates the concept and components of OTM. The core elements are shown in the circles while the "arms" show examples of the types of applications that can be built onto OTM. Following the diagram are paragraphs explaining each of the components.



Oracle Data Base

OTM is built on the industry-standard Oracle Relational Database. Oracle's core product is the Oracle7™ database, a powerful data storage system capable of supporting nearly every major computer language as well as text, images, audio and video. In addition to the Oracle7 database, Oracle offers tools, applications, education and consulting services. Oracle's tools provide forms generation, sophisticated reporting and graphics, comprehensive data communications, and intelligent text management.

Oracle software runs on personal digital assistants, set-top devices, PCs, workstations, minicomputers, mainframes and massively parallel computers. Oracle is the leader in client/server computing, mainframe downsizing, and corporate reengineering. And it is the leading software for the emerging Information Highway.

Transportation Network Management

The Network Management function is used to create the overall transportation network. Once the network is established, inventory items can then be associated with the network using the preferred referencing system.

OTM can handle multiple types of transportation system network. It has been created with the specific intent of managing the total inter-modal transportation system. Individual networks can be created and maintained separately by mode of transportation (e.g. the roadway network, the rail network, etc.)

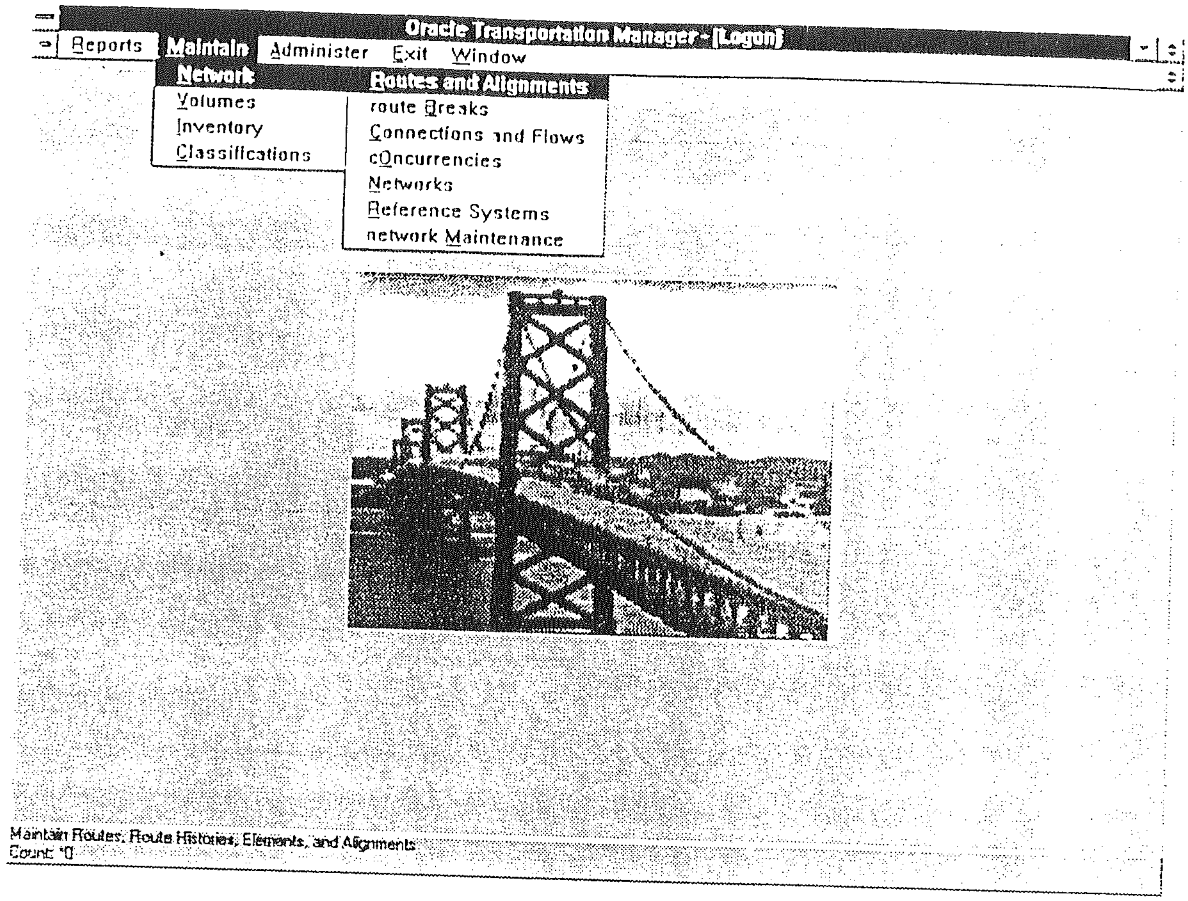
Special conditions along routes are also accommodated by the Network Management function. These conditions include alternate alignments between two sides of the same route, connections between routes, such as interchanges, intersections, and route crossings, concurrencies of two or more routes on the same physical infrastructure and breaks in routes.

OTM can also maintain information on the driving sequence or traffic flow of the route. This can range from simply recording that two routes intersect to defining what the valid traffic directional changes at the intersection are. OTM also can record traffic restrictions.

Below are the functions available within OTM to establish the transportation network:

- Maintain Networks
- Maintain Routes and Elements
- Maintain Route Breaks
- Maintain Route Concurrencies
- Maintain Route Independent Alignments
- Maintain Element Connections
- Maintain Route Intersections, Interchanges, and Crossovers
- Maintain Traffic Flow and Traffic Flow Details
- Maintain Alternate Reference methods
- Maintain Route Group Types
- Maintain Groups and Group Members

The basic Network Management menu items are shown on the following screen image.

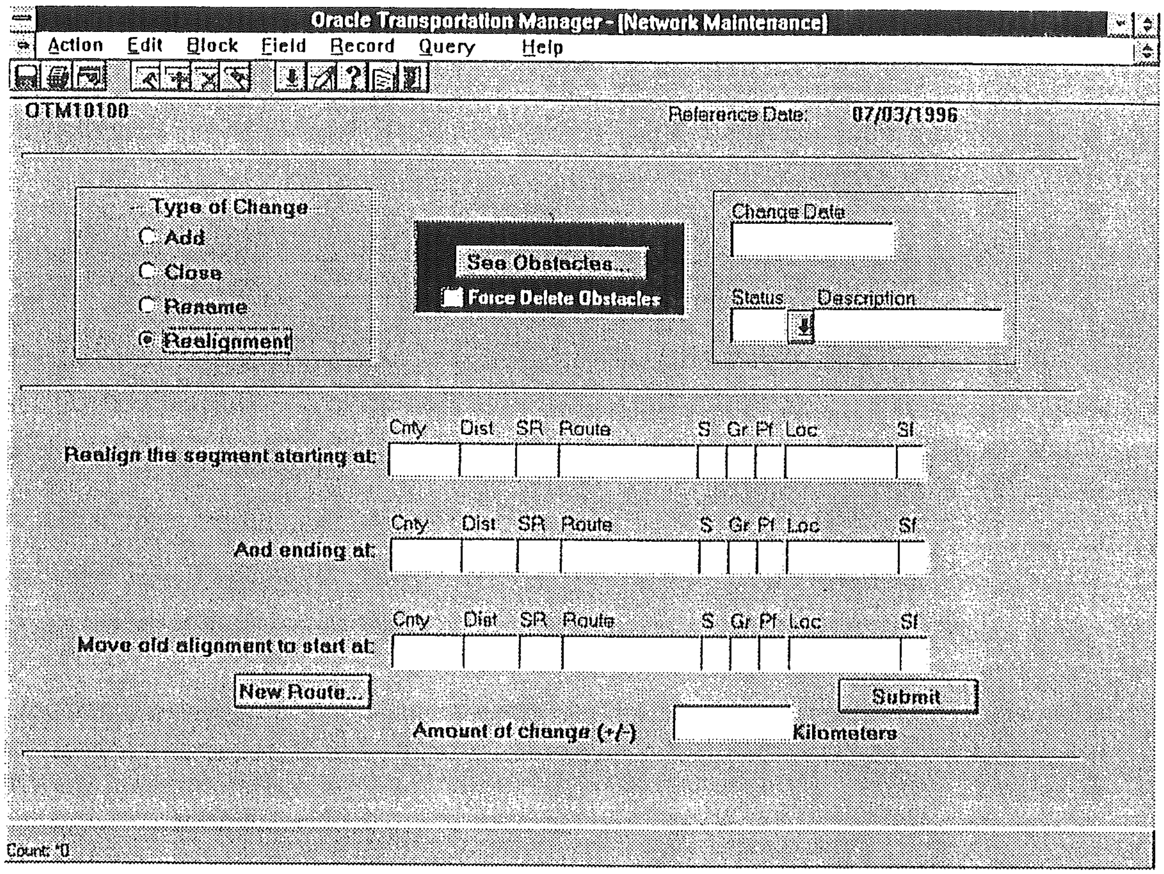


In addition to defining a network, Network Management includes special Network Maintenance functions. These are the types of processes that are normally very difficult to accommodate in legacy systems typically because the systems were developed to work within the transportation network as it existed when the system was created without regard to possible future changes. The design of OTM specifically includes the tools needed to keep the network up to date. The following OTM Network Maintenance functions are available within OTM:

- Add a Route Segment
- Close a Route Segment
- Rename a Route Segment
- Route Segment Realignment

When these processes are invoked, the affected segments are either closed by setting the END DATE or opened by adding the segment with a new BEGIN DATE (see the section below on DATED INVENTORY MANAGEMENT for a discussion on how OTM maintains data temporally). No segments are deleted from the system. All inventory on closed sections is likewise expired by setting the END DATE. If a Network Maintenance function results in a change in the overall route length, the locations of all of the inventory "downstream" of the change are automatically recalibrated to the correct position. Thus the user is not required to individually adjust the locations of existing inventory items.

Because both the network and the inventory records are maintained temporally, it is possible for the user to see the data as it existed at a given point in time. The following is an image of the Network Maintenance screen using a County/District/Route/Postmile type of referencing system.



Alternate Referencing Systems

It has been Oracle's experience that not all Departments of Transportation use the same referencing system. Although the easy answer would be to force all users of OTM to utilize a common system, practically speaking, this is not possible. Many agencies have significant investments in their data and would find it overwhelming to do a major conversion effort to an unfamiliar referencing system. Instead, OTM has the ability to use multiple reference methods. This allows inventory infrastructure information to be stored and accessed by any reference measurement scheme.

OTM maintains the location of the network and infrastructure inventory items using a base referencing system employing a linear offset reference method. This is the most efficient way to locate information within a transportation network. However, due to legacy systems, business rules, or user preference, most agencies do not reference their inventory data in this way. In fact, in many agencies, there are multiple ways of referencing locations within the same agency. Examples are:

- County Route and Milepost
- Landmark plus Offset
- Linear Referencing Systems
- Route and Offset
- Rail Route Number and Offset

Recognizing the uniqueness of each agencies methodology of referencing data, OTM's flexibility allows clients to set up their own particular referencing systems. The OTM System Administrator can set up a single or multiple referencing systems without additional programming or module customization. OTM creates cross-reference links between the base and alternate referencing systems.

Users can choose the preferred reference method at any time when or while logged on. All OTM data is available through these alternate reference methods to any user. Thus two users sitting side by side can be simultaneously viewing the same data using different referencing systems. Through data base views, the referencing systems can be extended to other software tools that connect to the Oracle database. This includes GIS systems, Oracle Data Browser, Excel, and other Microsoft Windows-based products.

When an alternate reference method is selected, the screens in OTM are dynamically changed to include the fields used for that system. For example, the above screen image shows a user-defined referencing system composed of County, District, SR, Route, route Suffix, GR, location Prefix, Location (milepost), location Suffix. With the exception of Route and Location, all other fields including the displayed prompts, are user-definable. So, for example, if a second reference method were defined with Route, Location, and County, those are the three fields that would appear on the screen.

Unit of Measure Management

OTM allows data to be stored in either Metric or English units. The System Administrator determines the unit in which the value is stored in the database as the Inventory Model within OTM is defined. However, as with referencing, the way the data is stored may not be the way all users want to see it. So OTM provides a User Preference that allows the user to select the type of units that the system is to display.

Within the OTM database structure, an available function converts data from Metric units to English units or vice versa. This flexible functionality is another Oracle solution added value. The application (both screens and reports), has the ability to display and input data items in three ways:

1. Display/update data in its native database structure
2. Display/update data in Metric units only
3. Display/update data in English units only

Dated Inventory Management

OTM utilizes the concept of date stamping changes to both the Network and the Inventory data. As a result, when the Network Maintenance functions (Add, Close, Rename, Realign) are invoked, the actual changes are implemented through the use of BEGIN DATE and END DATE fields. Old information is expired by setting the END DATE and new information is added with a BEGIN DATE. Likewise, the inventory template forms require both BEGIN DATE and END DATE as fields. The BEGIN DATE identifies the date on which the data became effective. The END DATE indicates the last day that this information was valid.

Through the use of this approach, expired data is not deleted from the system. Rather it is kept so that the user can make inquires into the state of the transportation network and inventory as of a specific date. In fact, OTM provides a REFERENCE DATE for each user as a User Preference which controls all of the information that the user sees. When a user logs onto OTM, the REFERENCE DATE defaults to the current date. However, the user can easily change the REFERENCE DATE to any date desired. From that point on (until the user either changes the date again or exits the system) the user will see the information from the data base as it existed on that date. As an example, assume that a user wants to determine what traffic signs were in place at a specific location prior to a roadway closure that occurred on June 17, 1993. By setting the REFERENCE DATE to June 16, 1993, he would see the network and the signs as they existed on that date.

Client-Definable Applications and Data Model

Once the OTM core has been installed and configured, the client-specific inventory data models and applications can be constructed around it. The Oracle CASE Tools allow clients to configure the OTM system to meet their specific needs. The model relationships are defined through CASE products including integrity constraints. The OTM application, with minimal programming, recognizes this custom Inventory and Data Model supporting the model throughout the application.

OTM takes full advantage of all Oracle7 database features such as:

- Distributed database tables
- Database triggers
- Database roles
- Database Integrity constraints
- Database primary and foreign key relationships
- Oracle CASE technology.

Other OTM Features

Data Storage/Dynamic Segmentation

OTM utilizes the principles of Dynamic Segmentation to store the inventory data. That is, for a given attribute, the value information is stored as a single entry from the point where the value begins to where it ends. There is no artificial static segmentation of the data as there has been in many legacy systems. For example, frequently the legacy systems have used the referencing system as the key to the data records. As a result, when one element of the referencing system changed, such as the County, a new record had to be created even if the data value stayed the same. So if a concrete road was built that crossed fifteen counties, there would be fifteen pavement records created. OTM, on the other hand, tracks the referencing system separately from the inventory and melds the two for the user. Thus, in this example, OTM would only create one entry for the concrete road that included its beginning and ending points.

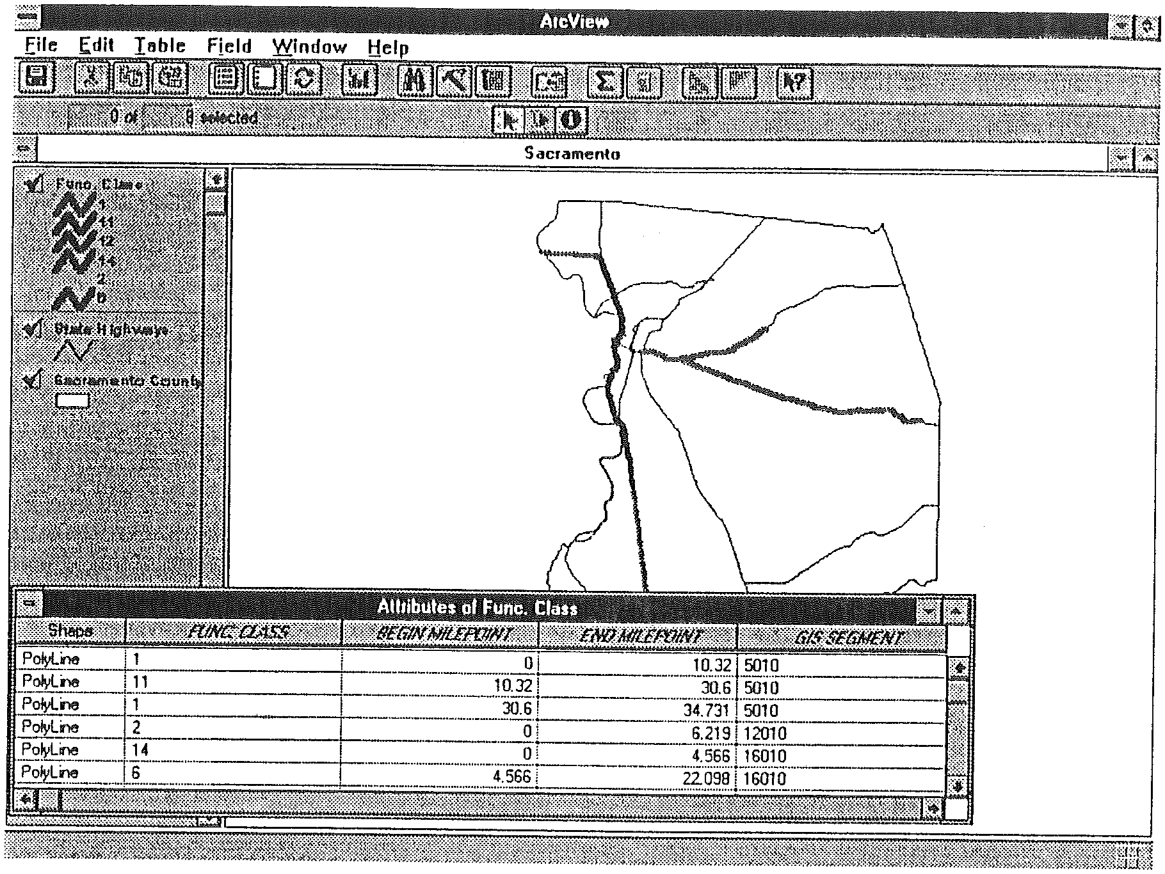
Since all of the inventory tables are constructed in this manner, OTM can relate information from the different inventory tables to each other based on their location on the network. Thus, the data can be viewed and updated in a simple, straightforward manner without concern for static segmentation.

Easy to Use Graphical User Interface

The OTM system uses Oracle Forms Version 4.5. The application runs under Windows in a client/server configuration. Because this is a Graphical User Interface (GUI) with on-line help, its is easy to use for even non-computer users. Data is accessed quickly and easily

GIS Integration

The application allows for easy integration with most Geographic Information Systems. OTM can be used with GIS products from ESRI, Intergraph, GDS, and most other GIS vendors. The following screen shows OTM data being accessed from ESRI's Arc/View product



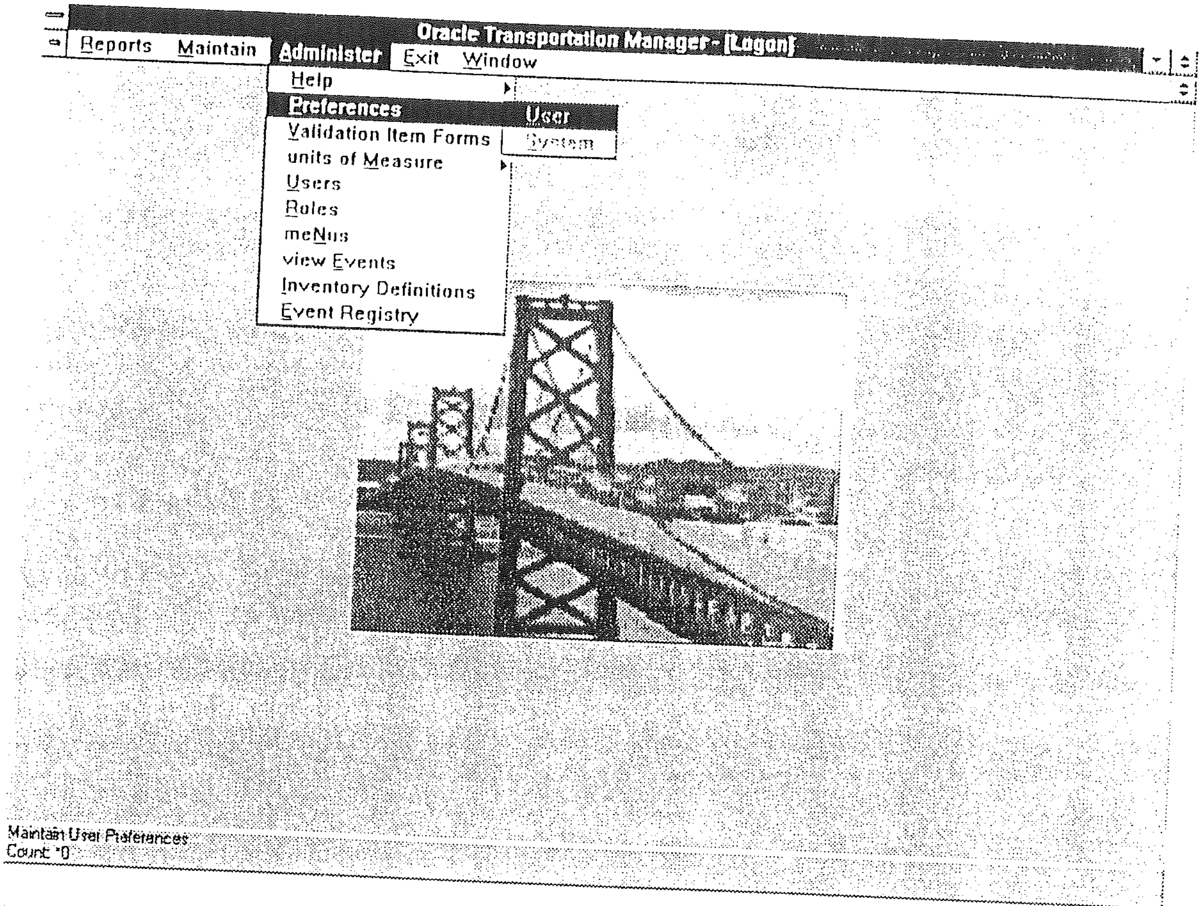
System Administration

The OTM application includes System Administration functions that easily allow the client Application Administrator to manage the system.

OTM's System Administration functions include:

- Maintain System Preferences
- Maintain Validation Tables
- Maintain Unit Conversion Factors
- Maintain User Information
- Maintain Role Information
- Maintain Menus
- Define Inventory

The following screen shows the items on the Administer menu.



The OTM product also integrates with other standard Oracle database administration modules, such as the Windows-based Oracle7 DBA Administration functions. These functions include:

- User Manager
- Object Manager
- Database Manager
- Role Manager

Query Builder

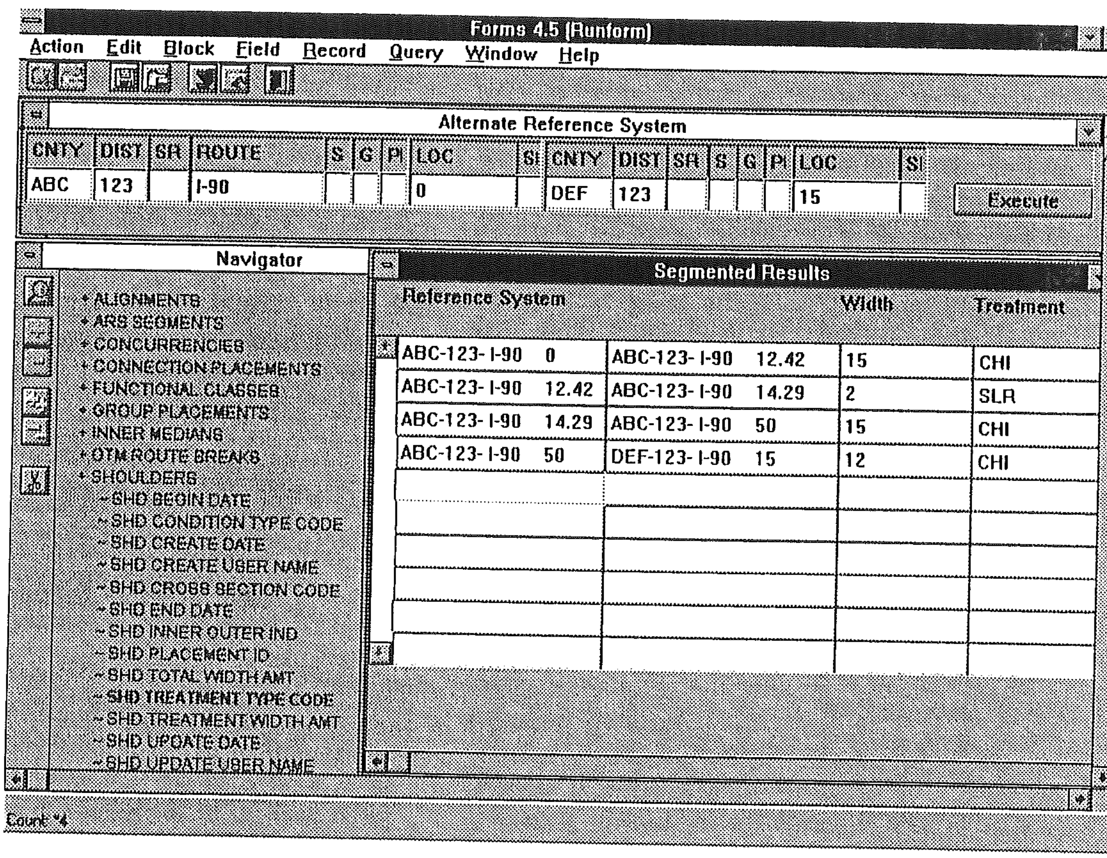
Because the inventory data is stored in multiple tables, OTM includes a dynamic Query Builder. This function allows the user to graphically select tables and attributes and construct a query that will simultaneously retrieve information from the various tables. This is the mechanism for answering questions such as "List all the pavement types, pavement conditions, accidents, traffic volumes, and signs on Route 50 in Adams county from milepost 10 through milepost 15." This is the kind of cross-system information that has been difficult to retrieve in the past. The Query Builder also allows users to select inventory data based on value changes in individual or multiple attributes. The resulting information would include all attribute data selected for reporting purposes. Users have the ability to define on-line what data attributes are to be extracted.

For each attribute selected, the user can choose various ways to create the results.

- Break on the data attribute value
- Summarize on the data attribute value
- Minimum value on segment
- Maximum value on segment
- Dominant value on segment
- Weighted average of value on segment
- First value found on segment
- Count number of values found on segment

The module can be used to create data files to be imported into other systems or for fixed reporting such as for Highway Performance Monitoring System (HPMS).

The following screen illustrates the use of the Query Builder.



In Summary, Oracle Transportation Manager:

+ Is a flexible *Enterprise Solution Enabler*
+ Was designed specifically to meet the needs of public and private transportation agencies
+ Maintains the core information on transportation networks
+ Provides for the integrated storage of data on the related infrastructure
+ Allows the simultaneous use of multiple referencing systems
+ Stores the network and inventory data temporally
+ Allows the simultaneous use of English and metric measurement systems
+ Can eliminate the "islands of information" common in DOT legacy systems
+ Performs complex network maintenance functions automatically
+ Allows the user to define the inventory data model
+ Provides the attribute data storage for information display through GIS systems
+ Is CASE-based and uses a fully relational database structure
+ Utilizes the most current ORACLE technology.

It is these capabilities that make Oracle Transportation Manager the *Solution of Choice* for transportation agencies.